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P.O. Box 2359  
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**TEST CABLE  
SELECTION**

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Parsons Hawaii  
Test Cable Selection

**MAY 1985**

**HAWAII DEEP WATER CABLE PROGRAM**

**FEDERALLY FUNDED - PHASE II**

**TEST CABLE  
SELECTION**

**PREPARED BY**

**THE RALPH M. PARSONS COMPANY**

**DBA PARSONS HAWAII**

**MAY 1985**



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SECTION 1  
INTRODUCTION

The cable selection task is another step towards accomplishing the goals and objectives of the Hawaii Deep Water Cable (HDWC) Program. The primary purpose of this task is the selection of a cable that best meets the Program's system and subsystem feasibility criteria [1 and 2]. The selected cable design forms the basis for the remainder of the Program's work efforts in the areas of design, manufacture and testing of the cable, cable vessel and cable handling equipment subsystems.

Cable selection encompasses consideration of cable design alternatives, cable vessel and cable handling equipment capabilities, route options, environmental conditions, cable subsystem configuration (i.e., number of cables, system voltage, power transfer requirements, etc.), electrical grid system reliability and availability alternatives and electric grid system capital and generation production costs. The following sections describe the selection procedure, data evaluated and factors considered in the selection process.

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Sections 2 and 3 provide data on the cable designs and routes considered during the cable selection task while Section 4 provides a key for the headings used in the numerous data tables incorporated in this report. The selection methodology and the evaluation sequence are reviewed in Section 5. Sections 6

through 13 present the details of the specific cable selection evaluation steps performed under this task.



## SECTION 2

### CABLE DESIGNS EVALUATED

Cable designs considered include those designs originally identified by Pirelli Cable Corporation (PCC) in the final Cable Design Parametric Study report (May 1985) [3] as "Solutions" as well as those cable designs that did not meet all of the electrical, thermal, mechanical and hydraulic constraints to be PCC "Solutions." The latter designs were evaluated to ensure that potentially attractive cable design alternatives were not prematurely eliminated.

The cable designs evaluated are listed on Table 1. A total of 192 aluminum conductor and 59 copper conductor cable designs were reviewed in the final test cable selection process. The cable designs use one of three electric design stress levels as shown in Table 2.

TABLE 1  
CABLE DESIGNS EVALUATED AS POTENTIAL TEST CANDIDATES<sup>1/</sup>

NO. OF EVALUATED CASES	CABLE TYPE	VOLTAGE RATING (kV)	MW RATING	CONDUCTOR MATERIAL
14	Solid	150	125	Al
16	Solid	200	125	Al
14	Solid	250	125	Al
6	Solid	300	125	Al
9	Solid	300	250	Al
2	Solid	400	125	Al
3	Solid	400	250	Al
15	SCOF 25 <sup>2/</sup>	150	125	Al
8	SCOF 25	200	125	Al
6	SCOF 25	200	250	Al
3	SCOF 25	250	125	Al
9	SCOF 25	250	250	Al
3	SCOF 25	300	125	Al
12	SCOF 25	300	250	Al
3	SCOF 25	400	125	Al
3	SCOF 25	400	250	Al
4	SCOF 25	400	500	Al
3	SCOF 25	600	125	Al
3	SCOF 25	600	250	Al
5	SCOF 25	600	500	Al
10	SCOF 50 <sup>3/</sup>	150	125	Al
6	SCOF 50	200	125	Al
6	SCOF 50	200	250	Al
9	SCOF 50	250	250	Al
7	SCOF 50	300	250	Al
3	SCOF 50	400	250	Al
6	SCOF 50	400	500	Al
4	SCOF 50	600	500	Al
4	Solid	150	125	Cu
4	Solid	200	125	Cu
3	Solid	250	125	Cu
3	Solid	300	125	Cu
3	Solid	250	250	Cu
3	Solid	300	250	Cu
3	SCOF 25	150	125	Cu
3	SCOF 25	200	125	Cu
3	SCOF 25	250	125	Cu
3	SCOF 25	300	125	Cu
3	SCOF 25	400	125	Cu
3	SCOF 25	600	125	Cu
2	SCOF 25	200	250	Cu
3	SCOF 25	250	250	Cu
4	SCOF 25	300	250	Cu
3	SCOF 25	400	250	Cu
3	SCOF 25	600	250	Cu
2	SCOF 25	400	500	Cu
4	SCOF 25	600	500	Cu

1/ The aluminum conductor designs all include splices capable of installation at 2,134 m (7,000 ft) depths, as required by the Cable Subsystem Feasibility Criteria [2]. Copper conductor cable designs were evaluated with and without splices.

2/ SCOF 25 refers to self-contained oil-filled cables with a 25 mm oil duct.

3/ SCOF 50 refers to self-contained oil-filled cables with a 50 mm oil duct.

**TABLE 2**
**CABLE ELECTRIC DESIGN STRESS LEVELS**

ELECTRIC DESIGN STRESS LEVEL	CABLE TYPE	
	SOLID PAPER	SCOF
Conservative	20 kV/mm	30 kV/mm
Standard	25 kV/mm	35 kV/mm
Advanced	30 kV/mm	40 kV/mm

### SECTION 3

#### ROUTE OPTIONS EVALUATED

Three route options (Figures 1, 2 and 3) have been utilized in the evaluation of the cable designs. The route options are as follows:

- Route Option 1 -- Hawaii to Oahu. One submarine leg 252 km (157 mi) long. No intermediate landings.
- Route Option 2 -- Hawaii to Maui to Oahu. Two submarine legs, 153 and 101 km (95 and 63 mi) long. One intermediate landing on Maui.
- Route Option 3 -- Hawaii to Maui to Molokai to Oahu. Three submarine legs, 99, 49 and 43 km (62, 49 and 27 mi) long. Intermediate landings on Maui and Molokai.

The Characterization of Potential Routes and Route Option Selection report [4] describes the investigations and analyses contributing to the definition of the three route options and details the route selection issues.

Route Option 2 is considered to be the most likely route alternative for a commercial interisland electrical power cable system because it presents the following advantages:

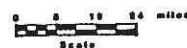
- In comparison to Route Option 1, which is all submarine, Route Options 2 and 3 provide an island hop(s) which allows reconfiguration of the cable system should there







APPROXIMATE DISTANCE WITHIN DEPTH RANGES FOR SUBMARINE PORTIONS (KM)							
SEGMENT	DEPTH (M)				1200-1500	1500-1800	1800+
	0-300	300-600	600-900	900-1200			
HD	22	5	5	-	-	-	-
HI	-	-	-	6	3	5	5
MG (por	30	8	10	-	-	-	-
MQ	44	-	-	-	-	-	-
MO	5	-	-	-	-	-	-
OC	21	14	8	-	-	-	-
TOTAL	122	27	23	6	3	5	5
$\bar{x}$	64.0	14.1	12.0	3.1	1.6	2.6	2.6



be any problems on any given cable leg (i.e., increases the overall system availability).

- In comparison to the all submarine route of Option 1, the landing on Maui in Route Options 2 and 3 easily permits a different cable design to be used in the shallower portions of the route.
- The Maui landing in Route Option 2 and the Maui and Molokai landings in Route Option 3 allow intermediate oil feeding stations for SCOF cable designs, significantly reducing cable hydraulic design constraints on those routes.
- Route Options 2 and 3 each allow interconnection with the Maui grid system if required or desired.
- In comparison to Route Option 1, Route Options 2 and 3 reduce the number of at-sea splices and vessel size requirements for a number of the cable designs.
- While Route Options 2 and 3 have a number of similar advantages over Route Option 1, Route Option 2 avoids potential opposition to overhead line segments in environmentally sensitive areas in Route Option 3.



Considering the advantages of Route Option 2, if all other cable design technical and cost factors are satisfactory, those cable designs suitable for Route Option 2 are favored. [4]

SECTION 4

EXPLANATION OF DATA TABLE HEADINGS

This report includes 18 summary data tables. The list below provides a key to the headings used on the data tables in this report.

TABLE COLUMN HEADING	DESCRIPTION
Case Number	PCC cable design identification No. Corresponds with cable design numbers used in Cable Design Parametric Study [1].
No. of Cables	Number of power cables in electric grid system configuration (Number does not include ground return cable, which is required for all configurations).
Cable Type	Design type of cable. Solid = Solid paper insulated; SCOF 25 = Self-contained oil filled cable with 25 mm oil duct; SCOF 50 = SCOF cable with 50 mm oil duct.
Voltage	Normal operating voltage rating of cable.
Load per cable (MW)	Normal maximum power transmission load rating for each cable.
MDI, TI, Cables, Repair, Manuf., EIO, EIT, Install	Abbreviations for the eight technical selection criteria defined in the Cable Selection Methodology (See Ref. 4).
Weighted Score	Selection criterion score multiplied by the associated "risk weight factor," as defined in the Cable Selection Methodology [5].
Route (or Rt)	The route option 1, 2, or 3 (as defined in Section 3) for which the cable system capital costs, production costs, splice and shipping requirements are evaluated.
Trans \$, Tot Cost Prod \$ (H), Tot Cost Prod \$ (L)	The three cost measures calculated for each cable design for each route. These are defined and discussed in Section 8.

TABLE COLUMN HEADING	DESCRIPTION
Max. Ship Length	The present maximum single-cable shipping length. (Based on cable factory turntable storage limitations, not based on vessel limitations).
Max. Manuf Length	The maximum length of cable that can be manufactured without factory splices (Based on existing factory capabilities).
Number of Splices	The total number of splices required (either factory splices or at-sea splices) for one cable for the entire route from Hawaii to Oahu (all cable segments).

A number of the tables included herein indicate the listed information is for cable "Candidates," which are those PCC design "Solutions" that theoretically meet all of the cable subsystem feasibility criteria. [2] There is one exception with regard to the cables shown as "candidates" in some of the data tables. The cable subsystem feasibility criteria require the cable to have a minimum mechanical design safety factor of 2.0 (equivalent to selection criterion of MDI = 2.0 or greater) to accommodate unexpected deployment/retrieval sea, weather, and control problems. To allow examination of more of the cable designs developed and to allow a better understanding of the implications of this safety factor requirement on cable "candidate" selection, designs ~~BELOW an MDI of 2.0 are shown on a number of the data tables for~~ reference only (they are NOT "candidates").

SECTION 5  
SELECTION METHODOLOGY

The selection methodology utilized and applied herein is described in the Cable Selection Methodology report [5].

To reduce data manipulation requirements, and to allow selection evaluations to proceed while additional cable designs were developed and total system costs calculated, the actual cable selection effort was completed in the sequence described below.

- (1) Identification of cable "candidates" for aluminum conductor designs (see Section 6).
- (2) Evaluation of aluminum conductor, standard electric design stress "candidates" based on application of technical selection criteria (see Section 7).
- (3) Evaluation of aluminum conductor, standard electric design stress "candidates" based on system cost analysis (see Section 8).
- (4) Selection of final aluminum conductor, standard electric design stress "candidates" based on combined technical and cost evaluations (see Section 9).



- (5) Technical and cost evaluation of conservative and advanced electric design stress, aluminum conductor cable designs (see Section 10).
- (6) Technical and economic evaluation of copper conductor cable designs (see Section 11).
- (7) Technical evaluation of aluminum conductor/copper tail cable system designs (see Section 12).
- (8) Final cable selection (see Section 13).

## SECTION 6

IDENTIFICATION OF CABLE "CANDIDATES"  
FOR ALUMINUM CONDUCTOR,  
STANDARD ELECTRIC STRESS BASED DESIGNS

Cable design "Solutions" were developed by PCC for a broad range of electrical, thermal, and oil feed length requirements specified in the Cable Design Parametric Study [3]. Table 3 provides a listing of all of the standard electric design stress, aluminum conductor, HDWC cable "Solutions" and associated relevant data. "Solutions" which are unacceptable due to oil feed length, thermal or electrical limitations associated with the three route options under consideration are noted.

All of the standard electric stress, aluminum conductor cable design "Solutions" were evaluated and compared against the Cable Subsystem Feasibility Criteria [2]. Those "Solutions" that theoretically meet all of the feasibility criteria were designated as "Candidates."

Of the 78 standard electric stress, aluminum conductor "Solutions," 55 of the designs satisfied all of the feasibility requirements for "candidates." Table 4 shows all 55 of the standard electric stress, aluminum conductor cable "candidates." The "candidates" include:

- Representatives of all of the cable design types (Solid, SCOF 25, and SCOF 50).

TABLE 4 LISTING OF ALL STANDARD STRESS, ALUMINUM CONDUCTOR, CABLE "CANDIDATES"

Case Number	No. of Cables	Cable Type	Voltage (kV dc)	Conductor Cross Section (sq. mm)	Transmission Load/Cable (MW)	Thermal Index	Rated Current (Amps)	Cable Finished Dia. (mm)	Cable Wt in Water (kg/m)	Max Ship Length (km)	Max Manuf Length (km)	Number Of Fac Splices (Route 1)	Number Of at-sea Splices (Route 1)	Max Oil Feed Dist (km)	NG-OF ON ROUTES	MDI (400') (Hs 8)	Score By MDI	Weighted MDI Score (WF=5.2)	Score by TI	Weight Score (WF=2.0)
43	4	SOLID	250	1400	125	2.31	500	115.2	23.8	163	35	6	1	N.A.		2.43	99	514	100	2
40	4	SOLID	250	1200	125	1.98	500	112.2	22.5	172	37	6	1	N.A.		2.39	96	498	98	2
72	4	SCOF 25	150	1200	125	1.93	833	101.4	19.7	202	52	3	1	145	1,2	2.41	98	507	93	2
86	4	SCOF 25	200	1200	125	3.59	625	105.4	20.9	189	45	5	1	375		2.39	96	501	100	2
75	4	SCOF 25	150	1600	125	2.56	833	107	21.9	181	43	5	1	320		2.35	93	485	100	2
37	4	SOLID	250	1100	125	1.82	500	110.8	22	176	39	5	1	N.A.		2.23	85	442	82	2
116	3	SCOF 25	300	1600	250	2.54	833	119.5	25.8	151	32	7	1	190	1	2.33	92	477	100	2
29	4	SOLID	200	1400	125	1.52	625	107.4	21.3	184	43	5	1	N.A.		2.44	100	518	52	1
49	4	SOLID	300	1200	125	2.91	417	121.4	25.4	150	30	7	1	N.A.		2.16	80	416	100	2
113	3	SCOF 25	300	1200	250	1.91	833	113.9	23.5	166	36	6	1	105	1,2	2.30	90	468	91	2
104	3	SCOF 25	250	2000	250	2.19	1000	120.2	26.5	147	30	7	1	200	1	2.28	88	459	100	2
119	3	SCOF 25	300	2000	250	3.19	833	124.6	28.3	138	28	8	1	370		2.30	90	467	100	2
78	4	SCOF 25	150	2000	125	3.21	833	112.6	24.2	164	37	6	1	435		2.29	89	463	100	2
116	4	SCOF 25	300	1600	250	2.54	833	119.5	25.8	151	32	7	1	190	1	2.33	92	477	100	2
83	4	SCOF 25	200	1000	125	3.00	625	102.1	19.6	202	49	5	1	220	1	2.22	85	440	100	2
101	3	SCOF 25	250	1600	250	1.75	1000	115.1	24.5	160	35	6	1	120	1,2	2.35	93	484	75	2
113	4	SCOF 25	300	1200	250	1.91	833	113.9	23.5	166	36	6	1	105	1,2	2.30	90	468	91	2
104	4	SCOF 25	250	2000	250	2.19	1000	120.2	26.5	147	30	7	1	200	1	2.28	88	459	100	2
47	4	SOLID	300	1100	125	2.66	417	120.3	24.8	154	32	7	1	N.A.		2.02	70	366	100	2
119	4	SCOF 25	300	2000	250	3.19	833	124.6	28.3	138	28	8	1	370		2.30	90	467	100	2
69	4	SCOF 25	150	1000	125	1.60	833	98.1	18.4	216	56	3	1	105	1,2	2.34	93	481	60	1
95	4	SCOF 25	250	1000	125	4.96	500	106.4	20.8	189	44	5	1	435		2.12	77	403	100	2
101	4	SCOF 25	250	1600	250	1.75	1000	115.1	24.5	160	35	6	1	120	1,2	2.35	93	484	75	2
34	4	SOLID	250	1000	125	1.66	500	109.2	21.2	182	40	5	1	N.A.		2.09	75	391	66	1
24	4	SOLID	200	1100	125	1.17	625	102.6	19.6	201	48	5	1	N.A.		2.45	100	520	17	
107	4	SCOF 25	300	1000	125	7.06	417	110.9	22.5	174	39	5	1	435		1.99	68	355	100	2
80	4	SCOF 25	200	800	125	2.40	625	98.9	18.3	216	54	3	1	140	1,2	1.88	61	316	100	2
21	4	SOLID	200	1000	125	1.08	625	100.7	18.8	209	52	4	1	N.A.		2.30	90	467	8	
124	3	SCOF 25	400	1200	250	3.51	625	123.7	26.6	145	28	8	1	220	1	2.08	74	387	100	2
32	4	SOLID	250	900	125	1.49	500	107.7	20.8	186	43	5	1	N.A.		1.91	63	326	49	1
147	4	SCOF 50	150	1600	125	3.06	833	124.6	27.2	141	28	8	1	435		2.38	95	495	100	2
124	4	SCOF 25	400	1200	250	3.51	625	123.7	26.6	145	28	8	1	220	1	2.08	74	387	100	2
121	4	SCOF 25	400	1200	125	14.63	313	123.7	26.6	145	28	8	1	435		2.08	74	387	100	2
156	4	SCOF 50	200	1600	125	5.56	625	128.4	28.5	134	25	9	1	435		2.36	94	488	100	2
168	3	SCOF 50	250	1600	250	1.94	1000	132.1	29.7	128	23	10	1	340		2.34	93	483	94	2
150	4	SCOF 50	150	2000	125	3.82	833	128.7	29.1	132	25	9	1	435		2.32	91	473	100	2
168	4	SCOF 50	250	1600	250	1.94	1000	132.1	29.7	128	23	10	1	340		2.34	93	483	94	2
144	4	SCOF 50	150	1200	125	2.29	833	120.1	24.9	154	30	8	1	435		2.19	83	429	100	2
153	4	SCOF 50	200	1200	125	4.17	625	123.9	26.1	146	28	8	1	435		2.11	77	399	100	2
137	2	SCOF 25	600	1600	500	2.46	833	150.8	36.9	101	17	12	2	130	1,2	2.09	75	390	100	2
140	2	SCOF 25	600	2000	500	3.08	833	154.6	38.8	96	15	15	2	220	1	2.19	82	427	100	2
175	3	SCOF 50	300	1600	250	3.00	833	136.1	31	122	22	10	2	435		2.33	92	477	100	2
171	3	SCOF 50	250	2000	250	2.42	1000	136.2	31.6	120	22	10	2	435		2.29	89	463	100	2
134	3	SCOF 25	600	1600	250	10.53	417	150.8	36.9	101	17	12	2	435		2.09	75	390	100	2
175	4	SCOF 50	300	1600	250	3.00	833	136.1	31	122	22	10	2	435		2.33	92	477	100	2
178	3	SCOF 50	300	2000	250	3.75	833	140.3	33	115	20	11	2	435		2.27	88	456	100	2
171	4	SCOF 50	250	2000	250	2.42	1000	136.2	31.6	120	22	10	2	435		2.29	89	463	100	2
131	4	SCOF 25	600	1600	125	42.86	208	150.8	36.9	101	17	12	2	435		2.09	75	390	100	2
134	4	SCOF 25	600	1600	250	10.53	417	150.8	36.9	101	17	12	2	435		2.09	75	390	100	2
178	4	SCOF 50	300	2000	250	3.75	833	140.3	33	115	20	11	2	435		2.27	88	456	100	2
165	3	SCOF 50	250	1200	250	1.45	1000	127.6	27.5	138	26	9	1	190	1	2.02	70	366	45	
181	3	SCOF 50	400	1600	250	5.36	625	144.7	34.2	110	18	12	2	435		2.23	85	442	100	2
165	4	SCOF 50	250	1200	250	1.45	1000	127.6	27.5	138	26	9	1	190	1	2.02	70	366	45	
181	4	SCOF 50	400	1600	250	5.36	625	144.7	34.2	110	18	12	2	435		2.23	85	442	100	2
191	2	SCOF 50	600	2000	500	3.51	833	167.7	43.6	84	12	18	2	435		2.17	81	421	100	2

Score by TI	Weighted TI Score (WF=2.7)	Score By # Of Cables	Weighted # Cables Score (WF=1.9)	Score By Repair	Weighted Repair Score (WF=3.4)	Score By Manuf.	Weighted Manuf. Score (WF=1.4)	Score By EID	Weighted EID Score (WF=1.0)	Score By EIT	Weighted EIT Score (WF=1.1)	Score By Install (Route 1)	Weighted Install Score (Route 1) (WF=3.4)	TOTAL TECHNICAL SELECTION SCORE	Total Rank Order
100	270	56.0	106	100	340	80	112	100	100	100	110	20	68	1621	1
98	266	56.0	106	100	340	80	112	100	100	100	110	20	68	1601	2
93	251	56.0	106	85	289	80	112	100	100	80	88	30	102	1555	3
100	270	56.0	106	85	289	80	112	100	100	80	88	20	68	1534	4
100	270	56.0	106	85	289	80	112	100	100	80	88	20	68	1518	5
82	221	56.0	106	100	340	80	112	100	100	100	110	25	85	1516	6
100	270	75.0	143	85	289	80	112	100	100	80	88	10	34	1513	7
52	139	56.0	106	100	340	80	112	100	100	100	110	25	85	1510	8
100	270	56.0	106	100	340	80	112	100	100	100	110	15	51	1506	9
91	246	75.0	143	85	289	80	112	100	100	80	88	15	51	1497	10
100	270	75.0	143	85	289	80	112	100	100	80	88	10	34	1494	11
100	270	75.0	143	85	289	80	112	100	100	80	88	5	17	1485	12
100	270	56.0	106	85	289	80	112	100	100	80	88	15	51	1479	13
100	270	56.0	106	85	289	80	112	100	100	80	88	10	34	1477	14
100	270	56.0	106	85	289	80	112	100	100	80	88	20	68	1473	15
75	204	75.0	143	85	289	80	112	100	100	80	88	15	51	1471	16
91	246	56.0	106	85	289	80	112	100	100	80	88	15	51	1461	17
100	270	56.0	106	85	289	80	112	100	100	80	88	10	34	1458	18
100	270	56.0	106	100	340	80	112	100	100	100	110	15	51	1455	19
100	270	56.0	106	85	289	80	112	100	100	80	88	5	17	1449	20
60	163	56.0	106	85	289	80	112	100	100	80	88	30	102	1442	21
100	270	56.0	106	85	289	80	112	100	100	80	88	20	68	1436	22
75	204	56.0	106	85	289	80	112	100	100	80	88	15	51	1435	23
66	177	56.0	106	100	340	80	112	100	100	100	110	25	85	1421	24
17	47	56.0	106	100	340	80	112	100	100	100	110	25	85	1420	25
100	270	56.0	106	85	289	80	112	100	100	80	88	20	68	1389	26
100	270	56.0	106	85	289	80	112	100	100	80	88	30	102	1383	27
8	22	56.0	106	100	340	80	112	100	100	100	110	30	102	1360	28
100	270	75.0	143	70	238	80	112	100	100	80	88	5	17	1354	29
49	132	56.0	106	100	340	100	140	100	100	100	110	25	85	1340	30
100	270	56.0	106	60	204	40	56	100	100	80	88	0	0	1319	31
100	270	56.0	106	70	238	80	112	100	100	80	88	5	17	1318	32
100	270	56.0	106	70	238	80	112	100	100	80	88	5	17	1318	33
100	270	56.0	106	60	204	40	56	100	100	80	88	-5	-17	1295	34
94	253	75.0	143	60	204	40	56	100	100	80	88	-10	-34	1292	35
100	270	56.0	106	60	204	40	56	100	100	80	88	-5	-17	1280	36
94	253	56.0	106	60	204	40	56	100	100	80	88	-10	-34	1256	37
100	270	56.0	106	60	204	40	56	100	100	80	88	0	0	1254	38
100	270	56.0	106	60	204	40	56	100	100	80	88	0	0	1223	39
100	270	100.0	190	70	238	80	112	100	100	80	88	-60	-204	1184	40
100	270	100.0	190	70	238	80	112	100	100	80	88	-75	-255	1170	41
100	270	75.0	143	60	204	40	56	100	100	80	88	-50	-170	1168	42
100	270	75.0	143	60	204	40	56	100	100	80	88	-50	-170	1154	43
100	270	75.0	143	70	238	80	112	100	100	80	88	-60	-204	1137	44
100	270	56.0	106	60	204	40	56	100	100	80	88	-50	-170	1132	45
100	270	75.0	143	60	204	40	56	100	100	80	88	-55	-187	1130	46
100	270	56.0	106	60	204	40	56	100	100	80	88	-50	-170	1118	47
100	270	56.0	106	70	238	80	112	100	100	80	88	-60	-204	1101	48
100	270	56.0	106	70	238	80	112	100	100	80	88	-60	-204	1101	49
100	270	56.0	106	60	204	40	56	100	100	80	88	-55	-187	1094	50
45	122	75.0	143	60	204	40	56	100	100	80	88	-5	-17	1062	51
100	270	75.0	143	45	153	40	56	100	100	80	88	-60	-204	1048	52
45	122	56.0	106	60	204	40	56	100	100	80	88	-5	-17	1026	53
100	270	56.0	106	45	153	40	56	100	100	80	88	-60	-204	1012	54
100	270	100.0	190	45	153	40	56	100	100	80	88	-90	-306	972	55



TABLE 6 LISTING OF ALL STANDARD STRESS, ALUMINUM CONDUCTOR, CABLE 'CANDIDATES'  
"CANDIDATES" LISTED IN RANK ORDER OF:

Case Number	No. of Cables	Cable Type	Voltage (kV dc)	Conductor Cross Section (sq. mm)	Load per Cable (MW)	Max Oil Feed Dist (km)	ROUTE # 1 >>>		Rank by Trans \$	Tot Cost		Rank by Tot Cost (H)	Tot Cost		Rank by Tot Cost (L)	ROUTE # 2 >>>		Rank by Trans \$	Tot Cost		To
							Trans \$	252 km Sub		Prod \$ (H)	Tot Cost (H)		Prod \$ (L)	Tot Cost (L)		Trans \$	153 km sub		Prod \$ (H)	Tot Cost	
113	4	SCOF 25	300	1200	250	105	NG - OF														
101	3	SCOF 25	250	1600	250	120	NG - OF														
80	4	SCOF 25	200	800	125	140	NG - OF														
137	2	SCOF 25	600	1600	500	130	NG - OF														
72	4	SCOF 25	150	1200	125	145	NG - OF														
101	4	SCOF 25	250	1600	250	120	NG - OF														
113	3	SCOF 25	300	1200	250	105	NG - OF														
69	4	SCOF 25	150	1000	125	105	NG - OF														
116	3	SCOF 25	300	1600	250	190	NG - OF														
104	3	SCOF 25	250	2000	250	200	NG - OF														
119	3	SCOF 25	300	2000	250	370	235.24		5	2328.74		1	2274.94		1						
124	3	SCOF 25	400	1200	250	220	NG - OF														
165	3	SCOF 50	250	1200	250	190	NG - OF														
168	3	SCOF 50	250	1600	250	340	253.02		14	2346.52		2	2292.72		8						
116	4	SCOF 25	300	1600	250	190	NG - OF														
104	4	SCOF 25	250	2000	250	200	NG - OF														
175	3	SCOF 50	300	1600	250	435	265.09		17	2358.59		3	2304.79		14						
171	3	SCOF 50	250	2000	250	435	265.14		18	2358.64		4	2304.84		15						
119	4	SCOF 25	300	2000	250	370	284.59		22	2364.59		5	2323.19		21						
140	2	SCOF 25	600	2000	500	220	NG - OF														
124	4	SCOF 25	400	1200	250	220	NG - OF														
178	3	SCOF 50	300	2000	250	435	274.95		20	2368.45		6	2314.65		18						
165	4	SCOF 50	250	1200	250	190	NG - OF														
168	4	SCOF 50	250	1600	250	340	305.54		30	2385.54		7	2344.14		28						
181	3	SCOF 50	400	1600	250	435	292.46		26	2385.96		8	2332.16		22						
191	2	SCOF 50	600	2000	500	435	304.78		29	2392.48		9	2336.18		24						
171	4	SCOF 50	250	2000	250	435	322.45		31	2402.45		10	2361.05		31						
175	4	SCOF 50	300	1600	250	435	323.34		32	2403.34		11	2361.94		32						
178	4	SCOF 50	300	2000	250	435	336.93		34	2416.93		12	2375.53		34						
21	4	SOLID	200	1000	125	N.A.	226.29		1	2423.19		13	2280.89		2						
134	3	SCOF 25	600	1600	250	435	329.95		33	2423.45		14	2369.65		33						
24	4	SOLID	200	1100	125	N.A.	229.86		2	2426.76		15	2284.46		3						
83	4	SCOF 25	200	1000	125	220	NG - OF														
32	4	SOLID	250	900	125	N.A.	234.64		3	2431.54		16	2289.24		4						
95	4	SCOF 25	250	1000	125	435	234.85		4	2431.75		17	2289.45		5						
34	4	SOLID	250	1000	125	N.A.	237.45		6	2434.35		18	2292.05		6						
86	4	SCOF 25	200	1200	125	375	237.53		7	2434.43		19	2292.13		7						
29	4	SOLID	200	1400	125	N.A.	239.51		8	2436.41		20	2294.11		9						
37	4	SOLID	250	1100	125	N.A.	241.68		9	2438.58		21	2296.28		10						
75	4	SCOF 25	150	1600	125	320	243.44		10	2440.34		22	2298.04		11						
40	4	SOLID	250	1200	125	N.A.	245.02		11	2441.92		24	2299.62		12						
181	4	SCOF 50	400	1600	250	435	360.56		35	2440.56		23	2399.16		35						
107	4	SCOF 25	300	1000	125	435	246.21		12	2443.11		25	2300.81		13						
43	4	SOLID	250	1400	125	N.A.	252.25		13	2449.15		26	2306.85		16						
78	4	SCOF 25	150	2000	125	435	255.18		15	2452.08		27	2309.78		17						
47	4	SOLID	300	1100	125	N.A.	261.67		16	2458.57		28	2316.27		19						
49	4	SOLID	300	1200	125	N.A.	265.74		19	2462.64		29	2320.34		20						
144	4	SCOF 50	150	1200	125	435	280.61		21	2477.51		30	2335.21		23						
153	4	SCOF 50	200	1200	125	435	285.54		23	2482.44		31	2340.14		25						
121	4	SCOF 25	400	1200	125	435	286.17		24	2483.07		32	2340.77		26						
147	4	SCOF 50	150	1600	125	435	289.52		25	2486.42		33	2344.12		27						
134	4	SCOF 25	600	1600	250	435	408.43		36	2488.43		34	2447.03		36						
156	4	SCOF 50	200	1600	125	435	298.14		27	2495.04		35	2352.74		29						
150	4	SCOF 50	150	2000	125	435	299.45		28	2496.35		36	2354.05		30						
131	4	SCOF 25	600	1600	125	435	408.51		37	2605.41		37	2463.11		37						

NOTES \*\*\*\*\*

1. NG - OF = Case does not meet oil feed length requirement.
2. All costs are \$Millions, PW 1983
3. Tot Cost = Total capital cost + total Oahu production costs  
H = high outage rate L = low outage rate

				ROUTE # 3 >>>					
Tot Cost Prod \$ (H)	Rank by Tot Cost (H)	Tot Cost Prod \$ (L)	Rank by Tot Cost (L)	Trans \$ 99 km sub	Rank by Trans \$	Total Cost Prod \$ (H)	Rank by Tot Cost (H)	Total Cost Prod \$ (L)	Rank by Tot Cost (L)
				219.39	24	2299.39	6	2257.99	10
				192.45	2	2285.95	2	2232.15	2
				202.63	6	2399.53	30	2257.23	9
				237.99	35	2325.69	17	2269.39	27
				208.26	15	2405.16	37	2262.86	19
				223.3	26	2303.3	8	2261.9	17
				188.7	1	2282.2	1	2228.4	1
				205.52	9	2402.42	33	2260.12	14
2319.58	1	2265.78	1	196.93	3	2290.43	3	2236.63	3
2321.91	2	2268.11	2	199.84	4	2293.34	4	2239.54	4
2331.36	3	2277.56	3	205.79	10	2299.29	5	2245.49	5
2332.68	4	2278.88	4	206.34	12	2299.84	7	2246.04	6
2340.99	5	2287.19	7	214.09	21	2307.59	9	2253.79	7
2349.22	6	2295.42	13	220.37	25	2313.87	12	2260.07	13
2351.76	7	2310.36	22	231.03	32	2311.03	10	2269.63	29
2353.84	8	2312.44	24	233.73	34	2313.73	11	2272.33	30
2361.38	9	2307.58	19	225.95	29	2319.45	13	2265.65	22
2361.41	10	2307.61	20	227.81	31	2321.31	14	2267.51	24
2367.87	11	2326.47	29	243.15	36	2323.15	15	2281.75	36
2368.72	12	2312.42	23	244.04	40	2331.74	20	2275.44	33
2369.61	13	2328.21	30	243.96	39	2323.96	16	2282.56	38
2371.36	14	2317.56	26	233.43	33	2326.93	18	2273.13	32
2376.5	15	2335.1	31	250.76	44	2330.76	19	2289.36	40
2388.72	16	2347.32	38	260.09	47	2340.09	22	2298.69	44
2389.09	17	2335.29	32	246.32	41	2339.82	21	2286.02	39
2395.23	18	2338.93	34	264.72	48	2352.42	25	2296.12	41
2405.93	19	2364.53	41	269.64	50	2349.64	24	2308.24	48
2406.9	20	2365.5	42	269.24	49	2349.24	23	2307.84	47
2420.59	21	2379.19	44	279.54	52	2359.54	26	2318.14	52
2425.35	22	2283.05	5	201.04	5	2397.94	29	2255.64	8
2426.91	23	2373.11	43	277.34	51	2370.84	27	2317.04	51
2428.96	24	2286.66	6	203.74	7	2400.64	31	2258.34	11
2430.97	25	2288.67	8	206.03	11	2402.93	34	2260.63	15
2433.82	26	2291.52	9	205.18	8	2402.08	32	2259.78	12
2434.56	27	2292.26	10	206.52	13	2403.42	35	2261.12	16
2436.66	28	2294.36	11	207.31	14	2404.21	36	2261.91	18
2437.2	29	2294.9	12	210.71	17	2407.61	39	2265.31	21
2438.69	30	2296.39	14	211.06	18	2407.96	40	2265.66	23
2440.92	31	2298.62	15	210.52	16	2407.42	38	2265.12	20
2443.15	32	2300.85	16	215.02	22	2411.92	43	2269.62	28
2444.28	33	2301.98	17	213.05	19	2409.95	41	2267.65	25
2444.52	34	2403.12	45	297.14	53	2377.14	28	2335.74	53
2446.09	35	2303.79	18	214.06	20	2410.96	42	2268.66	26
2451.57	36	2309.27	21	218.52	23	2415.42	44	2273.12	31
2454.98	37	2312.68	25	223.92	27	2420.82	46	2278.52	34
2461.1	38	2318.8	27	224.5	28	2421.4	47	2279.1	35
2465.2	39	2322.9	28	227.59	30	2424.49	48	2282.19	37
2480.61	40	2338.31	33	243.19	37	2440.09	49	2297.79	42
2485.59	41	2343.29	35	247.1	42	2444	51	2301.7	45
2486.47	42	2344.17	36	243.94	38	2440.84	50	2298.54	43
2489.6	43	2347.3	37	249.95	43	2446.85	52	2304.55	46
2492.85	44	2451.45	46	336.1	54	2416.1	45	2374.7	54
2498.29	45	2355.99	39	256.65	45	2453.55	53	2311.25	49
2499.61	46	2357.31	40	257.48	46	2454.38	54	2312.08	50
2609.82	47	2467.52	47	336.14	55	2533.04	55	2390.74	55

TABLE 15 LISTING OF ALL STANDARD STRESS COPPER CONDUCTOR DESIGNS

Case Number	No. of Cables	Cable Type	Voltage (kV dc)	Conductor Cross Section (sq. mm)	Trans Load per Cable (MW)	Thermal Index	Rated Current (Amps)	Cable Finished Dia. (mm)	Cable Wt in Water (kg/m)	Max Ship Length (km)	Max Manuf Length (km)	# of Factory Splices (Rt 1)	# of At-sea Splices (Rt 1)	Max Oil Feed Length (km)	NG-OF ON ROUTES	Elec. Design Safety Factor	MDI W/O Joint	MDI With Joint	Score by MDI W/O Joint	Weighted MDI W/O Score (WF=5.2)	Score by MDI With Joint	Weighted MDI With Score (WF=5.2)
219	4	SCOF 25	250	600	125	4.88	500	105.9	29.3	146	53	3	1	260		3.63			72	376	29	15
216	4	SCOF 25	200	600	125	3.13	625	101.6	27.8	155	62	3	1	170	1	3.42	2.04	1.43	71	368	28	14
222	4	SCOF 25	300	600	125	6.98	417	110.9	30.8	138	47	4	1	260		3.67	2.07	1.44	74	384	31	16
214	4	SCOF 25	150	800	125	2.34	833	101.4	29.4	149	63	3	1	130	1,2	3.24	1.99	1.39	68	355	27	14
220	4	SCOF 25	250	800	125	6.59	500	109.9	32.2	133	48	4	1	260		3.53	2.04	1.43	72	373	30	15
218	4	SCOF 25	200	1000	125	5.50	625	108.7	33.5	130	49	4	1	260		3.44	2.01	1.42	70	364	29	13
217	4	SCOF 25	200	800	125	4.23	625	105.4	30.8	141	54	4	1	260		3.44	2.01	1.41	70	364	28	14
215	4	SCOF 25	150	1000	125	3.06	833	104.6	32.1	136	56	4	1	260		3.26	1.99	1.41	68	356	28	14
203	4	SOLID	250	800	125	2.12	500	110.3	29.6	142	44	5	1	N.A.		4.56	2.01	1.09	70	363	7	3
204	4	SOLID	300	600	125	2.07	417	119.9	31.5	130	35	6	1	N.A.		5.45	2.03	1.11	71	372	8	4
205	4	SOLID	300	700	125	2.53	417	120.2	32.4	127	33	6	1	N.A.		4.31	2.03	1.11	71	370	8	4
236	3	SCOF 25	300	600	250	1.56	833	110.9	30.8	138	47	4	1	75	1,2,3	3.34	2.07	1.44	74	384	31	16
202	4	SOLID	250	700	125	1.84	500	108.8	28.2	148	47	5	1	N.A.		4.31	2.01	1.09	70	363	6	3
213	4	SCOF 25	150	600	125	1.71	833	97.4	25.8	168	72	3	1	85	1,2,3	3.15	1.96	1.36	67	347	25	13
200	4	SOLID	200	900	125	1.68	625	102.9	27.8	154	55	3	1	N.A.		3.95	2.00	1.08	69	359	6	3
238	3	SCOF 25	300	1000	250	2.83	833	117.6	36.5	117	39	4	2	160	1	3.51	2.04	1.45	72	376	31	16
234	3	SCOF 25	250	1200	250	2.35	1000	116.1	37.7	115	40	4	2	150	1,2	3.34	2.03	1.45	71	369	31	16
231	3	SCOF 25	200	1600	250	2.09	1250	117.6	41.2	107	39	4	2	160	1	3.2	1.97	1.42	67	349	29	15
235	3	SCOF 25	250	1600	250	3.31	1000	121.7	43.3	101	35	5	2	260		3.37	2.01	1.45	70	363	31	16
233	3	SCOF 25	250	1000	250	1.95	1000	113.1	35	123	44	4	2	110	1,2	3.31	2.03	1.44	71	370	30	15
232	3	SCOF 25	200	2000	250	2.75	1250	122.9	46.6	95	33	5	2	260		3.25	1.97	1.43	67	347	30	15
237	3	SCOF 25	300	800	250	2.16	833	114.4	34.1	125	41	6	2	110	1,2	3.45	2.07	1.46	74	384	32	17
239	3	SCOF 25	300	1200	250	3.41	833	120.4	39.3	110	36	6	2	260		3.53	2.03	1.45	72	372	31	16
224	4	SCOF 25	300	1000	125	12.00	417	117.6	36.5	117	39	4	2	260		3.49	2.04	1.45	72	376	31	16
221	4	SCOF 25	250	1000	125	8.45	500	113.1	35	123	44	4	2	260		3.46	2.03	1.44	71	370	30	15
201	4	SOLID	250	600	125	1.51	500	107.6	27.2	153	47	5	1	N.A.		4.65	2.01	1.09	70	365	6	3
199	4	SOLID	200	800	125	1.40	625	101.2	26.6	161	56	3	1	N.A.		4.18	1.99	1.07	68	355	5	2
240	3	SCOF 25	400	600	250	2.80	625	121.7	35.6	117	35	6	2	110	1,2	3.89	2.14	1.50	79	410	35	18
223	4	SCOF 25	300	800	125	9.38	417	114.4	34.1	125	41	6	2	260		3.56	2.07	1.46	74	384	32	17
241	3	SCOF 25	400	800	250	3.82	625	124.7	38.1	110	32	6	2	220	1	3.94	2.11	1.49	77	400	34	18
247	2	SCOF 25	400	2000	500	2.53	1250	140.1	53.8	80	23	9	3	160	1	3.48	2.02	1.47	70	365	32	17
206	4	SOLID	300	800	125	2.91	417	121	33.5	123	33	6	2	N.A.		4.14	2.04	1.12	72	375	9	4
242	3	SCOF 25	400	1000	250	5.00	625	127.6	40.5	104	30	7	2	260		3.94	2.09	1.48	75	391	33	18
196	4	SOLID	150	1200	125	1.31	833	101.1	29.6	148	56	3	1	N.A.		3.46	2.00	1.08	69	358	6	3
198	4	SOLID	200	700	125	1.22	625	99.3	24.9	171	60	3	1	N.A.		4.27	1.97	1.06	67	348	4	2
246	2	SCOF 25	400	1600	500	1.91	1250	135.4	49	87	25	9	2	110	1,2	3.41	2.05	1.48	73	378	33	18
225	4	SCOF 25	400	600	125	11.76	313	121.7	35.6	117	35	6	2	260		3.79	2.14	1.50	79	410	35	18
226	4	SCOF 25	400	800	125	15.79	313	124.7	38.1	110	32	6	2	260		3.67	2.11	1.49	77	400	34	17
249	2	SCOF 25	600	1000	500	2.47	833	151.9	51.2	80	18	12	3	120	1,2	4.15	2.14	1.52	79	409	36	19
195	4	SOLID	150	1100	125	1.24	833	99.3	28	156	60	3	1	N.A.		3.46	1.97	1.07	67	350	5	2
227	4	SCOF 25	400	1000	125	20.69	313	127.6	40.5	104	30	7	2	260		3.59	2.09	1.48	75	391	33	18
250	2	SCOF 25	600	1200	500	2.99	833	153.6	53.6	77	17	13	3	160	1	4.19	2.11	1.51	77	400	35	18
248	2	SCOF 25	600	800	500	1.86	833	150.2	49.1	83	19	12	3	85	1,2,3	4.01	2.15	1.53	80	414	36	19
243	3	SCOF 25	600	600	250	6.00	417	148.7	47.1	86	19	12	2	260		4.48	2.19	1.55	82	427	38	20
251	2	SCOF 25	600	1600	500	4.26	833	157.4	58.4	71	17	14	3	260		4.21	2.07	1.49	74	385	34	18
244	3	SCOF 25	600	800	250	8.11	417	150.2	49.1	83	19	12	3	260		4.2	2.15	1.53	80	414	36	19
245	3	SCOF 25	600	1000	250	10.53	417	151.9	51.2	80	18	12	3	260		4.02	2.14	1.52	79	409	36	19
197	4	SOLID	200	600	125	N.G.	625	97.4	23.9	178	65	3	1	N.A.		3.88	1.96	1.05	67	347	4	2
193	4	SOLID	150	900	125	N.G.	833	95.4	25.3	172	69	3	1	N.A.		3.42	1.95	1.05	66	343	4	2
194	4	SOLID	150	1000	125	1.07	833	97.4	26.9	162	65	3	1	N.A.		3.43	1.98	1.07	68	352	5	2
207	3	SOLID	250	1000	250	N.G.	1000	113.2	32.2	132	40	5	1	N.A.		3.39	2.02	1.11	71	367	7	3
208	3	SOLID	250	1100	250	N.G.	1000	114.8	33.5	127	39	6	1	N.A.		3.49	2.03	1.11	71	371	8	3
228	4	SCOF 25	600	600	125	25.00	208	148.7	47.1	86	19	12	2	260		4.04	2.19	1.55	82	427	38	20
229	4	SCOF 25	600	800	125	33.33	208	150.2	49.1	83	19	12	3	260		3.91	2.15	1.53	80	414	36	19
230	4	SCOF 25	600	1000	125	42.86	208	151.9	51.2	80	18	12	3	260		3.82	2.14	1.52	79	409	36	19
212	3	SOLID	300	1200	250	1.11	833	125.4	38	110	30	7	2	N.A.		4.01	2.04	1.13	72	376	9	4
211	3	SOLID	300	1100	250	1.04	833	124.3	37.1	113	32	6	2	N.A.		4.02	2.05	1.13	72	376	9	4
210	3	SOLID	300	1000	250	N.G.	833	123.1	35.4	117	32	6	2	N.A.		3.95	2.03	1.12	72	372	8	3
209	3	SOLID	250	1200	250	N.G.	1000	116.2	34.5	123	37	6	2	N.A.		3.51	2.03	1.12	71	369	8	3

## NOTES \*\*\*\*\*

All copper conductor cases listed on Table 16 do not qualify as "Candidates" because MDI with joints is below 2.0. Cases noted as "Unacceptable due to MDI" in the right most column do not meet the 2.0 requirement even without a joint.

re DI th nt	Weighted MDI With Score (WF=5.2)	Score By TI	Weighted TI Score (WF=2.7)	Score By # of Cables	Weighted # Cables Score (WF=1.9)	Score By Repair	Weighted Repair Score (WF=3.4)	Score By Manuf	Weighted Manuf Score (WF=1.4)	Score By EIO	Weighted EIO Score (WF=1.0)	Score By EIT	Weighted EIT Score (WF=1.1)	Score By Install	Weighted Install Score (WF=3.4)	TOTAL TECHNICAL SELECTION SCORE (W/O Joints)	TOTAL TECHNICAL SELECTION SCORE (With Joints)	TECH RANK (W/O Joints)	TECH RANK (With Joints)	UNACCEPT DESIGN DUE TO (See key)
29	153	100	270	56	106	85	289	80	112	100	100	80	88	35	119	1460	1238	5	1	
28	147	100	270	56	106	85	289	80	112	100	100	80	88	35	119	1453	1231	7	2	OF - 1
31	160	100	270	56	106	85	289	80	112	100	100	80	88	30	102	1451	1227	8	3	
27	141	100	270	56	106	85	289	80	112	100	100	80	88	35	119	1440	1226	10	4	OF - 1,2 ,MDI
30	155	100	270	56	106	85	289	80	112	100	100	80	88	30	102	1440	1223	9	5	
29	152	100	270	56	106	85	289	80	112	100	100	80	88	30	102	1431	1220	11	6	
28	148	100	270	56	106	85	289	80	112	100	100	80	88	30	102	1431	1215	12	7	
28	146	100	270	56	106	85	289	80	112	100	100	80	88	30	102	1424	1213	13	8	MDI
7	34	100	270	56	106	100	340	100	140	100	100	100	110	25	85	1514	1186	1	9	
8	40	100	270	56	106	100	340	100	140	100	100	100	110	20	68	1506	1175	2	10	
8	40	100	270	56	106	100	340	100	140	100	100	100	110	20	68	1504	1175	3	11	
31	160	56	152	75	143	85	289	80	112	100	100	80	88	30	102	1369	1145	16	12	OF - 1,2,3
6	33	84	226	56	106	100	340	100	140	100	100	100	110	25	85	1470	1141	4	13	
25	131	71	193	56	106	85	289	80	112	100	100	80	88	35	119	1354	1138	17	14	OF - 1,2,3 ,MDI
6	30	68	183	56	106	100	340	100	140	100	100	100	110	35	119	1458	1128	6	15	
31	163	100	270	75	143	85	289	80	112	100	100	80	88	-20	-68	1309	1096	21	16	OF - 1
31	160	100	270	75	143	85	289	80	112	100	100	80	88	-20	-68	1302	1094	22	17	OF - 1,2
29	152	100	270	75	143	85	289	80	112	100	100	80	88	-20	-68	1282	1085	26	18	OF - 1 ,MDI
31	161	100	270	75	143	85	289	80	112	100	100	80	88	-25	-85	1280	1078	27	19	
30	158	95	256	75	143	85	289	80	112	100	100	80	88	-20	-68	1289	1077	24	20	OF - 1,2
30	155	100	270	75	143	85	289	80	112	100	100	80	88	-25	-85	1264	1072	31	21	MDI
32	165	100	270	75	143	85	289	80	112	100	100	80	88	-30	-102	1283	1064	25	22	OF - 1,2
31	163	100	270	75	143	85	289	80	112	100	100	80	88	-30	-102	1271	1062	29	23	
31	163	100	270	56	106	85	289	80	112	100	100	80	88	-20	-68	1273	1060	28	24	
30	158	100	270	56	106	85	289	80	112	100	100	80	88	-20	-68	1267	1055	30	25	
6	33	51	137	56	106	100	340	100	140	100	100	100	110	25	85	1383	1051	14	26	
5	26	40	109	56	106	100	340	100	140	100	100	100	110	35	119	1379	1051	15	27	MDI
35	180	100	270	75	143	70	238	80	112	100	100	80	88	-30	-102	1258	1028	35	28	OF - 1,2
32	165	100	270	56	106	85	289	80	112	100	100	80	88	-30	-102	1247	1028	38	29	
34	177	100	270	75	143	70	238	80	112	100	100	80	88	-30	-102	1248	1026	37	30	OF - 1
32	167	100	270	100	190	70	238	80	112	100	100	80	88	-45	-153	1210	1012	43	31	OF - 1
9	44	100	270	56	106	100	340	100	140	100	100	100	110	-30	-102	1340	1009	18	32	
33	174	100	270	75	143	70	238	80	112	100	100	80	88	-35	-119	1222	1006	40	33	
6	30	31	83	56	106	100	340	80	112	100	100	100	110	35	119	1329	1001	19	34	
4	22	22	59	56	106	100	340	100	140	100	100	100	110	35	119	1323	996	20	35	MDI
33	172	91	246	100	190	70	238	80	112	100	100	80	88	-45	-153	1199	993	45	36	OF - 1,2
35	180	100	270	56	106	70	238	80	112	100	100	80	88	-30	-102	1222	992	41	37	
34	177	100	270	56	106	70	238	80	112	100	100	80	88	-30	-102	1212	990	42	38	
36	189	100	270	100	190	70	238	80	112	100	100	80	88	-60	-204	1203	983	44	39	OF - 1,2
5	25	24	64	56	106	100	340	80	112	100	100	100	110	35	119	1302	977	23	40	MDI
33	174	100	270	56	106	70	238	80	112	100	100	80	88	-35	-119	1186	969	46	41	
35	184	100	270	100	190	70	238	80	112	100	100	80	88	-65	-221	1177	961	47	42	OF - 1
36	189	86	233	100	190	70	238	80	112	100	100	80	88	-60	-204	1171	947	49	43	OF - 1,2,3
38	196	100	270	75	143	70	238	80	112	100	100	80	88	-60	-204	1174	943	48	44	
34	178	100	270	100	190	70	238	80	112	100	100	80	88	-70	-238	1145	938	52	45	
36	189	100	270	75	143	70	238	80	112	100	100	80	88	-60	-204	1160	936	50	46	
36	189	100	270	75	143	70	238	80	112	100	100	80	88	-60	-204	1156	935	51	47	
4	19	0	0	56	106	100	340	100	140	100	100	100	110	35	119	1262	934	32	48	Therm ,MDI
4	19	0	0	56	106	100	340	100	140	100	100	100	110	35	119	1259	934	34	49	Therm ,MDI
5	24	7	20	56	106	100	340	80	112	100	100	100	110	35	119	1259	932	33	50	MDI
7	38	0	0	75	143	100	340	80	112	100	100	100	110	25	85	1257	928	36	51	Therm
8	41	0	0	75	143	100	340	80	112	100	100	100	110	20	68	1243	913	39	52	Therm
38	196	100	270	56	106	70	238	80	112	100	100	80	88	-60	-204	1138	907	53	53	
36	189	100	270	56	106	70	238	80	112	100	100	80	88	-60	-204	1124	900	54	54	
36	189	100	270	56	106	70	238	80	112	100	100	80	88	-60	-204	1120	899	55	55	
9	46	11	30	75	143	100	340	80	112	100	100	100	110	-35	-119	1091	762	56	56	
9	46	4	11	75	143	100	340	80	112	100	100	100	110	-30	-102	1090	760	57	57	
8	44	0	0	75	143	100	340	80	112	100	100	100	110	-30	-102	1075	746	58	58	Therm
8	42	0	0	75	143	100	340	80	112	100	100	100	110	-30	-102	1071	744	59	59	Therm



- Cable designs for two, three, and four-cable electric grid system configurations.
- Cable designs for normal power transfer ratings of 125, 250 and 500 MW.
- Cable designs with rated normal operating voltage ranging from 150 to 600 kV.
- Cable designs suitable for use on all route options.

**SECTION 7****TECHNICAL EVALUATION OF  
STANDARD ELECTRIC DESIGN STRESS,  
ALUMINUM CONDUCTOR CABLE "CANDIDATES"**

The technical evaluation of cable "candidates" was based on the methodology and technical criteria defined in the Cable Selection Methodology [5]. Table 4 shows the technical scores and rank for all of the standard electric stress, aluminum conductor "candidates."

**SECTION 8****SYSTEM COST EVALUATION OF  
ALUMINUM CONDUCTOR, STANDARD  
ELECTRIC DESIGN STRESS "CANDIDATES"**

Three costs were calculated for each cable design/system configuration for each route. They are designated on the data tables as:

- Trans \$
- Tot Cost Prod \$ (H)
- Tot Cost Prod \$ (L)

"Trans \$" for each route option is the total estimated 1983 present worth cost for the cable system, including:

- Cable and losses
- Overhead line and losses
- HVDC equipment
- Laying and splicing
- Pumping plants for SCOF cables
- Landing costs
- Potheads

"Trans \$," neglecting losses, which are only a small part of the "Trans \$," is the estimated total capital cost required for a commercial interisland electrical power cable system in Hawaii.

"Tot Cost Prod \$" for each route option is the "Trans \$" for each "candidate" plus the TOTAL Oahu production cost associated with that system configuration on a 1983 present worth basis. Present worth to the 1983 base year has been calculated using a 29-year period. The (H) indicates that the production costs are estimated assuming a high outage rate for the HVDC cable system. The (L) indicates that a low outage rate for the cable system was assumed.

The cables were assumed to have outage rates of once every ten years [(L) case] or once every 2.5 years [(H) case] and be out of service for six months during an outage event. These assumptions give unavailability levels of 0.05 and 0.20 respectively. Details with regard to the cable and system cost analysis, system studies, and production cost analysis are provided in the Final Systems Studies Report, No. R84-83, prepared by Power Technologies, Inc. [6].

The cable subsystem configuration outage rate has significant implications on total system cost because it affects production costs. Table 5 shows Oahu production costs and related cost differences for the various cable subsystem configuration and outage conditions.



TABLE 5  
PRODUCTION COSTS FOR VARIOUS  
CABLE CONFIGURATION AND OUTAGE RATES

CONFIGURATION: H = HIGH OUTAGE L = LOW OUTAGE		TOTAL OAHU PRODUCTION COST (\$ Millions)	COST DIFFERENCE DUE TO CHANGE IN OUTAGE RATE (\$ Millions)
3 x 250 MW	H	2,093.5	53.8
	L	2,039.7	
4 x 250 MW	H	2,080.0	41.4
	L	2,038.6	
4 x 125 MW	H	2,196.9	142.3
	L	2,054.6	
2 x 500 MW	H	2,087.7	56.3
	L	2,031.4	

Variation in outage rate has the most significant impact on the estimated total cost for the 125 MW cable "candidates." This is because loss of a cable with a 125 MW system configuration requires the system power transfer level to be reduced while the cable is out of service. The power not transmitted through the HDWC cable subsystem must then be supplied from Oahu, oil-based generation. [6]

"Tot Cost Prod \$ (H)" is the cost measure used to evaluate the cable "candidates" since it is the only cost measure which highlights the cost implications of outage rate. Use of "Trans \$" or "Tot Cost Prod \$ (L)" would indicate little difference between 125, 250 and 500 MW cable design options.

The "Trans \$," "Tot Cost Prod \$ (H)" and "Tot Cost Prod \$ (L)" for each cable design (standard electric stress, aluminum conductor) on each route option are shown in Table 6. Examination of the cost data reveals the following:

- The lowest total cost "candidates" for Route Options 1, 2, and 3 are all:

- SCOF - 25mm duct
- 300 kV
- 250 MW
- three-cable configurations

- The three lowest cost "candidates" for Route Options 2 and 3 are all SCOF 25, 250 MW, in the 250 to 300 kV range.

- The lowest cost "candidates" are:

- For Route Option 1 = Case 119
- For Route Option 2 = Case 116
- For Route Option 3 = Case 113

**SECTION 9****SELECTION OF FINAL ALUMINUM CONDUCTOR,  
STANDARD ELECTRIC DESIGN STRESS "CANDIDATES"  
BASED ON COMBINED TECHNICAL AND COST EVALUATIONS**

The calculated total cost (capital, losses and production costs) and cost rank for each of the technical "candidates" with a total technical score in the top 8 percent of all of the aluminum "candidates" is shown in Table 7.

The three top standard electric stress, aluminum conductor candidates based on both technical and cost ranking are:

- Case 119 -- Acceptable for all route options
- Case 116 -- Acceptable for route options 2 or 3
- Case 113 -- Acceptable for route option 3 only

All of the above "candidates" are SCOF 25 mm, 300 kV, 250 MW cables, and provide three-cable system configurations. They differ only in the conductor size (to allow proper oil feeding for each given route length). Based on Route Option 2 being the most likely commercial cable system route, the final selection for a standard electric stress, aluminum conductor cable is Design Case 116.

TABLE 7

COST, TECHNICAL SCORE AND RANKINGS  
FOR THE TECHNICAL "CANDIDATES" WITHIN THE  
TOP 8 PERCENT OF THE TECHNICAL SCORES

CASE NO.	NO. OF CABLES	CABLE TYPE	VOLTAGE (kV)	TECH SCORE	TECH RANK	TOTAL COST *	COST RANK
43	4	SOLID	250	1621	1	2452	36
40	4	SOLID	250	1601	2	2444	33
72	4	SCOF 25	150	1555	3	2440	31 ++
86	4	SCOF 25	200	1534	4	2437	29
75	4	SCOF 25	150	1518	5	2443	32
37	4	SOLID	250	1516	6	2441	31
116	3	SCOF 25	300	1513	7	2320	1
29	4	SOLID	200	1510	8	2439	30
49	4	SOLID	300	1506	9	2465	39
113	3	SCOF 25	300	1497	10	2310	1 ++
104	3	SCOF 25	250	1494	11	2322	2
119	3	SCOF 25	300	1485	12	2331	3

NOTES:

\* All costs are \$Millions, present worth (PW) 1983. Total Cost and Cost Rank are based on the use of Route Option 2 and production costing based on high (H) cable outage rate. Use of other Route Option costing does not change the cost rank order significantly.

++ Case Nos. 72 and 113 are limited due to oil feeding requirements to Route Option 3 and were thus only costed originally for route 3. For cost comparison only, if these designs could be used for Route Option 2, Case No. 72 would cost approximately \$2,440 million and be ranked approximately 31. Case No. 113 would cost approximately \$2,310 million and be ranked 1.



## SECTION 10

### TECHNICAL AND COST EVALUATION OF CONSERVATIVE AND ADVANCED ELECTRIC DESIGN STRESS, ALUMINUM CONDUCTOR CABLE DESIGNS

The evaluation thus far has only considered standard electric stress, aluminum conductor design cables. In addition to the standard electric stress, aluminum conductor designs (25 kV/mm for solid paper insulated cables and 35 kV/mm for SCOF cables), conservative and advanced electric stress aluminum conductor designs have been considered. These stress levels are defined as follows:

STRESS LEVEL -----	SOLID PAPER -----	SCOF -----
Conservative	20 kV/mm	30 kV/mm
Advanced	30 kV/mm	40 kV/mm

The standard electric stress levels were designated as such because they are commonly used in the cable industry worldwide. Performance with the standard electric stress level is well documented in laboratory testing and actual service. The alternative design electric stress options have been evaluated in terms of the potential benefits and penalties associated with each design stress option as compared with the standard level.

Table 8 summarizes the types of benefits and penalties associated with moving to a conservative or advanced electric stress design as compared to the standard stress design level.

TABLE 8

COMPARISON OF ALTERNATIVE CABLE  
DESIGN ELECTRIC STRESS OPTIONS

	CONSERVATIVE STRESS DESIGN	STANDARD STRESS	ADVANCED STRESS DESIGN
POTENTIAL BENEFITS	Higher EIO Higher EIT Improved BIL	<----->	Reduced Weight Improved Strength Smaller Diameter Improved Thermal Performance Lower Cost
POTENTIAL PENALTIES	Increase Weight Larger Diameter Reduced Strength Reduced Thermal Performance Higher Cost	<----->	Lower EIO Lower EIT Reduced Elec Life Lower BIL

### 10.1 EVALUATION OF CONSERVATIVE DESIGN STRESS OPTION

Potential benefits of a cable utilizing a conservative electric stress design include higher "Electrical Index for Normal Operating Conditions" (EIO), higher "Electrical Index for Transient Conditions" (EIT) and improved Basic Impulse Level (BIL). Table 9 shows EIT, EIO, and BIL values for the three stress design levels being evaluated.

The advantages of a conservative stress design are not of great value, since EIO, EIT and BIL are already acceptable for the standard stress design, which has been proven acceptable in years of commercial experience.

The technical penalties associated with the conservative electric stress design include reduced cable strength (MDI), increased weight and reduced thermal tolerance (TI). Considering the mechanical and thermal risks (uncertainties) in Hawaiian waters, these penalties significantly outweigh the limited electrical benefits.

The conservative electric stress design cables have a higher capital cost compared to a similar rated standard electric stress cable. This is due to their increased paper dielectric thickness and increased sheath material requirements (due to the larger diameter over the insulation).

TABLE 9

ELECTRICAL CHARACTERISTICS OF CABLE DESIGNS  
FOR THREE DESIGN STRESS LEVELS

ITEM	SOLID			SCOF		
Design Service Stress (kV/mm)	20	25	30	30	35	40
Minimum Impulse + DC strength(kV/mm)	85	85	85	90	90	90
Max Expected Impulse Stress Design Service Stress x 2.15	43	54	65	65	75	86
Cable BIL Capability	4.3	3.4	2.8	3.0	2.6	2.3
EIT	2.0	1.6	1.3	1.4	1.2	1.0
EIO *	3+	3+	3+	3+	3+	3+

\* Note: EIO varies with each cable design. All of the cable designs being evaluated have EIO equal to or greater than 3.0 and are considered equally acceptable. For simplification EIO is shown as "3+" for all designs on Table 9.



With no apparent net advantage of the conservative electric stress aluminum conductor cable designs, the analysis of these designs was truncated.

#### 10.2 EVALUATION OF ADVANCED ELECTRIC STRESS ALUMINUM CONDUCTOR DESIGN OPTIONS

The advanced electric stress aluminum conductor cable design "Solutions" were compared to the selected final standard electric stress cable "candidates" for each route option (see Table 10). These advanced stress designs fail to meet two of the defined Cable Subsystem Feasibility Criteria [2]. First, PCC states that "these cables should be limited to no polarity reversal," but polarity reversal is a system requirement. Second, the advanced stress design SCOF cables do not meet the minimum BIL requirements. BIL of the advanced SCOF cable is only 2.3, compared to the feasibility criterion minimum of 2.58. [3]

The failure of the advanced electric stress designs to meet all of the defined cable subsystem feasibility criteria eliminates them as "candidates," but additional technical and cost factors were analyzed to ensure the advanced stress designs were not truncated prematurely in the selection process. Manufacturing, shipping and splicing data for representative advanced and standard stress cable designs are presented in Table 11. Cost and cable design data for selected advanced electric stress cables are presented in Tables 12 and 13. Evaluation of these

TABLE 10

COMPARISON OF ADVANCED STRESS DESIGN SOLUTIONS  
TO SELECTED FINAL STANDARD STRESS DESIGN  
"CANDIDATES" FOR EACH ROUTE OPTION  
(Aluminum Conductor Cable Designs Only)

ITEM	STANDARD STRESS CANDIDATE	ADVANCED STRESS CANDIDATE	% DIFFERENCE FROM STANDARD DESIGN
ROUTE NO. 1			
Case Number	119	120	--
No. of Cables	3	3	--
Cable Type	SCOF 25	SCOF 25	--
Voltage (kV dc)	300	300	--
Conductor Cross Section	2,000	2,000	--
Trans Load/Cable (MW)	250	250	0
Losses at Rated (kW/km)	9.9	9.9	0
Thermal Index (TI)	3.19	3.24	1.57
Cable Diameter (mm)	124.6	121.4	-2.57
Cable Weight in Water	28.3	27.3	-3.53
Max. Oil Feed Distance	252+	252+	0
MDI	2.3	2.3	0
No. Factory Splices	8	7	-12.50
No. At-Sea Splices	1	1	0
No. Ship Loadings	2	2	0
Trans \$	235.24	228.86	-2.71
ROUTE NO. 2			
Case Number	116	117	--
No. of Cables	3	3	--
Cable Type	SCOF 25	SCOF 25	--
Voltage (kV dc)	300	300	--
Conductor Cross Section	1,600	1,600	--
Trans Load/Cable (MW)	250	250	0
Losses at Rated (kW/km)	12.4	12.4	0
Thermal Index (TI)	2.54	2.58	1.57
Cable Diameter (mm)	119.5	116.2	-2.76
Cable Weight in Water	25.8	24.7	-4.26
Max. Oil Feed Distance	190	210	10.53
MDI	2.33	2.33	0
No. Factory Splices	7	7	0
No. At-Sea Splices	1	0	-100.00
No. Ship Loadings	2	2	0.00
Trans \$	226.08	--	--
ROUTE NO. 3			
Case Number	113	114	--
No. of Cables	3	3	--
Cable Type	SCOF 25	SCOF 25	--
Voltage (kV dc)	300	300	--
Conductor Cross Section	1,200	1,200	--
Trans Load/Cable (MW)	250	250	--
Losses at Rated (kW/km)	16.8	16.8	0
Thermal Index (TI)	1.91	1.94	1.33
Cable Diameter (mm)	113.9	110.6	-2.90
Cable Weight in Water	23.5	22.5	-4.26
Max. Oil Feed Distance	105	115	9.52
MDI	2.3	2.39	3.91
No. Factory Splices	4	4	0
No. At-Sea Splices	0	0	0
No. Ship Loadings	2	2	0
Trans \$	188.70	--	--

TABLE 11 MANUFACTURING, SHIPPING, & SPLICING DATA FOR SELECTED CABLE DESIGNS

Case Number	Cable Type	Voltage (kV dc)	Conductor Cross Section (sq. mm)	Load Per Cable (MW)	Maximum Manuf Length (km)	Maximum Ship Length (km)	Number Factory Splices (Rt 1)	Number Factory Splices (Rt 2)	Number Factory Splices (Rt 3)	Weight In Air (kg/m)	Maximum Shipping Weight (Short Tons)	Ship DWT Cap (Short Tons)	Number of Ship Loadings (Rt 1)	Number of Ship Loadings (Rt 2)	Number of Splices at Sea (Rt 1)	Number of Splices at Sea (Rt 2)	Number of Splices at Sea (Rt 3)
STANDARD STRESS ALUMINUM CONDUCTOR CABLE DESIGNS																	
21	SOLID	200	1000	125	52	209	4	3	1	26.2	6031.9	19000	2	2	1	0	0
24	SOLID	200	1100	125	48	201	5	5	3	27.3	6044.6	19000	2	2	1	0	0
29	SOLID	200	1400	125	43	184	5	5	3	29.8	6040.1	19000	2	2	1	0	0
32	SOLID	250	900	125	43	186	5	5	3	29.4	6023.8	19000	2	2	1	0	0
34	SOLID	250	1000	125	40	182	5	5	4	30.1	6034.6	19000	2	2	1	0	0
37	SOLID	250	1100	125	39	176	5	5	4	31.2	6048.9	19000	2	2	1	0	0
40	SOLID	250	1200	125	37	172	6	6	4	31.9	6044.1	19000	2	2	1	0	0
43	SOLID	250	1400	125	35	163	6	6	4	33.7	6051.0	19000	2	2	1	0	0
47	SOLID	300	1100	125	32	154	7	7	5	35.6	6039.2	19000	2	2	1	0	0
101	SCOF 25	250	1600	250	35	160	NG-OF	NG-OF	4	34.3	6045.4	19000	NG-OF	NG-OF	NG-OF	NG-OF	0
104	SCOF 25	250	2000	250	30	147	NG-OF	7	5	37.2	6023.8	19000	NG-OF	3	NG-OF	1	0
107	SCOF 25	300	1000	125	39	174	5	5	4	31.5	6037.7	19000	2	2	1	0	0
113	SCOF 25	300	1200	250	36	166	NG-OF	NG-OF	4	33.0	6034.4	19000	NG-OF	NG-OF	NG-OF	NG-OF	0
116	SCOF 25	300	1600	250	32	151	NG-OF	7	5	36.4	6054.6	19000	NG-OF	3	NG-OF	1	0
119	SCOF 25	300	2000	250	28	138	8	7	5	39.8	6050.2	19000	2	3	1	1	0
165	SCOF 50	250	1200	250	26	138	NG-OF	8	5	39.6	6019.8	19000	NG-OF	3	NG-OF	1	0
168	SCOF 50	250	1600	250	23	128	10	10	7	42.7	6020.7	19000	2	3	1	1	0
175	SCOF 50	300	1600	250	22	122	10	10	7	44.9	6034.1	19000	3	3	2	1	0
COPPER CONDUCTOR CABLE DESIGNS																	
204	SOLID	300	600	125	35	130	6	5	4	42.2	6043.2	19000	2	3	1	1	0
212	SOLID	300	1200	250	30	110	7	7	5	49.7	6022.3	19000	3	3	2	1	0
214	SCOF 25	150	800	125	63	149	3	3	1	36.9	6056.5	19000	2	3	1	1	0
216	SCOF 25	200	600	125	62	155	3	3	1	35.4	6044.3	19000	2	2	1	0	0
219	SCOF 25	250	600	125	53	146	3	3	1	37.5	6031.1	19000	2	3	1	1	0
222	SCOF 25	300	600	125	47	138	4	4	3	39.8	6050.2	19000	2	3	1	1	0
239	SCOF 25	300	1200	250	36	110	6	6	4	50.0	6058.6	19000	3	3	2	1	0
241	SCOF 25	400	800	250	32	110	6	7	5	49.6	6010.1	19000	3	3	2	1	0
243	SCOF 25	600	600	250	19	86	12	11	8	63.8	6044.1	19000	3	4	2	2	1
ADVANCED STRESS ALUMINUM CONDITION CABLE DESIGNS																	
22	SOLID	200	1000	125	60	226	3	3	1	24.2	6024.7	19000	2	2	1	0	0
25	SOLID	200	1100	125	56	218	3	3	1	25.1	6027.5	19000	2	2	1	0	0
33	SOLID	250	900	125	52	211	4	3	1	26.0	6043.2	19000	2	2	1	0	0
35	SOLID	250	1000	125	50	204	4	5	1	26.9	6044.9	19000	2	2	1	0	0
41	SOLID	250	1200	125	44	191	5	5	3	28.7	6038.4	19000	2	2	1	0	0
44	SOLID	250	1400	125	41	180	5	5	4	30.5	6047.6	19000	2	2	1	0	0
105	SCOF 25	250	2000	250	32	151	7	7	5	36.3	6038.0	19000	2	3	1	1	0
117	SCOF 25	300	1600	250	33	158	-	7	4	34.6	6022.0	19000	2	2	1	0	0
120	SCOF 25	300	2000	250	29	144	7	7	5	38.2	6059.5	19000	2	3	1	1	0
169	SCOF 50	250	1600	250	25	133	9	9	5	41.2	6036.1	19000	2	3	1	1	0

NG-OF = Case does not meet oil feed length requirement for the given route.

TABLE 12

COST AND CABLE DATA FOR SELECTED ADVANCED STRESS,  
ALUMINUM CONDUCTOR CABLE SOLUTIONS

CASE NO.	22	25	33	35	120	169	120	169
No. of Cable	4	4	4	4	4	4	3	3
Cable Type	Solid	Solid	Solid	Solid	SCOF 25	SCOF 50	SCOF 25	SCOF 50
Voltage (kV dc)	200	200	250	250	300	250	300	250
Conductor Cross Section (sq mm)	1000	1100	900	1000	2000	1600	2000	16000
Trans Load per Cable (MW)	125	125	125	125	250	250	250	250
Rated Current (Amps)	625	625	500	500	833	1000	833	1000
Cable Finished Diameter (mm)	95.7	97.7	100.4	102.1	121.4	129.7	121.4	129.7
Cable Weight in Water (kg/m)	17.5	18.1	18.6	19.2	27.3	28.7	27.3	28.7
Maximum Oil Feed Length (km)	NA	NA	NA	NA	340	400	340	400
Maximum Allowable Pulling Tensions with Joint (met ton)								
MDI with Joint								
CASE NO. 1								
Total Trans \$ 252 km Sub	266.66	307.53	284.05	279.27	348.40	252.73	234.87	231.05
Total Cost Prod \$ (H)	2463.56	2387.53	2364.05	2359.27	2428.40	2346.23	2328.37	2324.55
Total Cost Prod \$ (L)	2321.26	2346.13	2322.65	2317.87	2387.00	2292.43	2274.57	2270.75
CASE NO. 2								
Total Trans \$ 252 km Sub	269.23	310.42	287.33	282.62	352.35	254.97	237.49	233.69
Total Cost Prod \$ (H)	2466.13	2390.42	2367.33	2362.62	2432.35	2348.47	2330.99	2327.19
Total Cost Prod \$ (L)	2323.83	2349.02	2325.93	2321.22	2390.95	2294.67	2277.19	2273.39
CASE NO. 3								
Total Trans \$ 252 km Sub	228.28	259.26	242.75	238.71	290.60	217.94	205.51	202.21
Total Cost Prod \$ (H)	2425.18	2339.26	2322.75	2318.71	2370.60	2311.44	2299.01	2295.71
Total Cost Prod \$ (L)	2282.88	2297.86	2281.35	2277.31	2329.20	2257.64	2245.21	2241.91

TABLE 13

COST COMPARISON OF SELECTED ALUMINUM CONDUCTOR  
STANDARD AND ADVANCED STRESS CABLE DESIGN

ROUTE NO. 1 COST COMPARISON:

ADVANCED STRESS DESIGN				STD STRESS DESIGN		% Dif In Cost Std to Adv
Case No.	No. of Cables	Cable Type	Route 1 Trans \$	Case No.	Route 1 Trans \$	
22	4	Solid	216.56	21	226.29	-4.30
25	4	Solid	219.07	24	229.86	-4.69
33	4	Solid	218.30	32	234.64	-6.96
35	4	Solid	221.85	34	237.45	-6.57
120	4	SCOF 25	276.18	119	284.59	-2.96
169	4	SCOF 50	298.33	168	305.54	-2.36
120	3	SCOF 25	228.86	119	235.24	-2.71
169	3	SCOF 50	247.54	168	253.02	-2.17

Average difference in Trans \$ (Rt 1) --  
Std to Adv Stress =

-4.09

ROUTE NO. 2 COST COMPARISON:

ADVANCED STRESS DESIGN				STD STRESS DESIGN		% Dif In Cost Std to Adv
Case No.	No. of Cables	Cable Type	Route 2 Trans \$	Case No.	Route 2 Trans \$	
22	4	Solid	218.65	21	228.45	-4.29
25	4	Solid	221.17	24	232.06	-4.69
33	4	Solid	220.45	32	236.92	-6.95
35	4	Solid	224.03	34	239.76	-6.56
120	4	SCOF 25	279.40	119	287.87	-2.94
169	4	SCOF 50	301.66	168	308.72	-2.29
120	3	SCOF 25	231.43	119	237.86	-2.70
169	3	SCOF 50	250.20	168	255.72	-2.16

Average difference in Trans \$ (Rt 2) --  
Std to Adv Stress =

-4.07

NOTES:

1. The cables being compared are exactly the same except for the electric design stress.
2. "Trans \$" is \$millions, present worth 1983.



data show the technical and economic benefits associated with the advanced stress design (Table 14).

In addition to not meeting all of the defined feasibility criteria, there is presently only limited laboratory data and no commercial service experience to support a cable design utilizing an advanced electric design stress level. For example, PCC notes the following: [3]

"...Extended and systematic long-term tests are only partially available..."

"...Expected changes in lifetime do not seem to be of major concern ALTHOUGH SERVICE EXPERIENCE AND LABORATORY DATA DO NOT GIVE TOTALLY CLEAR EVIDENCE OF THAT..."

Thus, the advanced electric stress cable designs score 60 percent lower than the standard electric stress cable designs with regard to the Design/Manufacturing Technology selection criterion. The implication is that significantly more laboratory testing of the dielectric materials and the full-scale cable would be required of an advanced design to reduce its technological uncertainty to a level comparable with standard electric design stress alternatives.

Failure of the advanced electric stress cable designs to comply with all of the cable subsystem feasibility criteria and unproven long-term electrical lifetime characteristics, outweigh the benefits of minor improvements to cable size and limited cost reduction. Thus, with no apparent net advantage of the advanced electric stress cable designs as compared to the standard stress

TABLE 14

TECHNICAL AND ECONOMIC BENEFITS OF ADVANCED  
ELECTRIC STRESS CABLE DESIGNS  
AS COMPARED TO STANDARD STRESS CABLE DESIGNS

TYPE OF BENEFIT	MAGNITUDE OF BENEFIT
Reduced Weight	4 percent reduction.
Improved Strength	No improvement (as measured by MDI) for large conductor sizes (1,600 sq mm +).  Approximately a 4 percent improvement on a 1,200 sq mm conductor (Cable of Route 3 only).
Smaller Diameter	Average 2.7 percent reduction.
Thermal Performance	No significant change.
Lower Cost	On average 4 percent lower cost. For SCOF cables an average reduction of 2.7 percent.

designs, the advanced stress cable designs have been eliminated from further consideration.

## SECTION 11

TECHNICAL AND ECONOMIC EVALUATION OF  
COPPER CONDUCTOR CABLE DESIGNS

Thus far, all of the cable designs reviewed and evaluated utilize aluminum as the conductor material. The original finding in the Cable Design Parametric Study [3] was that no copper conductor designs qualified as "Solutions." Due to the concern that copper conductor cable designs had been prematurely eliminated, additional copper conductor design analysis was pursued.

PCC developed 59 copper conductor cable designs based on the same parametric ranges used in the development of the aluminum conductor cable designs. Unlike the aluminum conductor cable designs, the copper conductor cable designs are shown even if they do not qualify as "Solutions." Design information for these was provided for two conditions: (1) with splices and (2) without splices. A listing of all standard electric stress, copper conductor cable designs is provided in Table 15. Cost information for selected copper conductor cable designs is shown in Table 16. Manufacturing, shipping and splicing information for the copper conductor cable designs is shown in Table 11. Table 17 provides a comparison of copper conductor cable designs to the selected standard stress, aluminum conductor "candidates."

The potential benefits of copper conductor cable designs as compared to aluminum conductor designs include:

TABLE 16

COST DATA FOR SELECTED  
STANDARD STRESS COPPER CONDUCTOR CABLE DESIGNS

CASE NO.	204	212	239	241	243	212	239	241	243	248
No. of Cables	4	4	4	4	4	3	3	3	3	2
Cable Type	Solid	Solid	SCOF 25	SCOF 25	SCOF 25	Solid	SCOF 25	SCOF 25	SCOF 25	SCOF 25
Voltage (kV dc)	300	300	300	400	600	300	300	400	600	600
Conductor Cross Sec. (sq mm)	600	1200	1200	800	600	1200	1200	800	600	800
Trans Load per Cable (MW)	125	250	250	250	250	250	250	250	250	500
CASE NO. 1										
Total Trans \$ 252 km Sub	266.66	307.53	284.05	279.27	348.40	252.73	234.87	231.05	284.68	244.69
Total Cost Prod \$ (H)	2463.56	2387.53	2364.05	2359.27	2428.40	2346.23	2328.37	2324.55	2378.18	2332.39
Total Cost Prod \$ (L)	2321.26	2346.13	2322.65	2317.87	2387.00	2292.43	2274.57	2270.75	2324.38	2276.09
CASE NO. 2										
Total Trans \$ 252 km Sub	269.23	310.42	287.33	282.62	352.35	254.97	237.49	233.69	287.78	248.61
Total Cost Prod \$ (H)	2466.13	2390.42	2367.33	2362.62	2432.35	2348.47	2330.99	2327.19	2381.28	2336.31
Total Cost Prod \$ (L)	2323.83	2349.02	2325.93	2321.22	2390.95	2294.67	2277.19	2273.39	2327.48	2280.01
CASE NO. 3										
Total Trans \$ 252 km Sub	228.28	259.26	242.75	238.71	290.60	217.94	205.51	202.21	243.03	219.46
Total Cost Prod \$ (H)	2425.18	2339.26	2322.75	2318.71	2370.60	2311.44	2299.01	2295.71	2336.53	2307.16
Total Cost Prod \$ (L)	2282.88	2297.86	2281.35	2277.31	2329.20	2257.64	2245.21	2241.91	2282.73	2250.86

TABLE 17

COMPARISON OF COPPER CONDUCTOR DESIGN OPTIONS  
TO SELECTED FINAL STANDARD STRESS  
ALUMINUM "CANDIDATES" FOR EACH ROUTE OPTION

ITEM	ALUMINUM STANDARD STRESS CANDIDATE	250 MW COPPER CANDIDATE	% DIF FROM AL DESIGN	125 MW COPPER CANDIDATE	% DIF FROM AL DESIGN
ROUTE NO. 1					
Case Number	119	239	--	219	--
No. of Cables	3	3	0	4	33.33
Cable Type	SCOF 25	SCOF 25	--	SCOF 25	--
Voltage (kV dc)	300	300	--	250	--
Cond. Cross Section	2,000	1,200	--	600	--
Trans Load/Cable(MW)	250	250	0	125	--
Thermal Index (TI)	3.19	3.41	0	4.88	52.98
Cable Diameter (mm)	124.6	120.4	-3.37	105.9	-15.01
Cable Wt. in Water	28.3	39.3	38.87	29.3	3.53
MDI	2.3	1.45	-36.96	1.43	-37.83
No. Factory Splices	8	6	-25.00	3	-62.50
No. At-Sea Splices	1	2	100	1	0
No. Ship Loadings	2	3	50	2	0
ROUTE NO. 2					
Case Number	116	238	--	216	--
No. of Cables	3	3	0	4	33.33
Cable Type	SCOF 25	SCOF 25	--	SCOF 25	--
Voltage (kV dc)	300	300	--	200	--
Cond. Cross Section	1,600	1,000	--	600	--
Trans Load/Cable(MW)	250	250	0	125	--
Thermal Index (TI)	2.54	2.83	11.42	3.13	23.23
Cable Diameter (mm)	119.5	117.6	-1.59	101.6	-14.98
Cable Wt. in Water	25.8	36.5	41.47	27.8	7.75
MDI	2.33	1.45	-37.77	1.41	-39.48
No. Factory Splices	7	4	0	3	-57.14
No. At-Sea Splices	1	1	0	0	0
No. Ship Loadings	2	3	0	2	-33.33
ROUTE NO. 3					
Case Number	113	114	--	216	0
No. of Cables	3	3	--	4	33.33
Cable Type	SCOF 25	SCOF 25	--	SCOF 25	--
Voltage (kV dc)	300	300	--	200	--
Cond. Cross Section	1,200	1,200	--	600	--
Trans Load/Cable(MW)	250	250	--	125	--
Thermal Index (TI)	1.91	1.94	1.33	3.13	63.87
Cable Diameter (mm)	113.9	110.6	-2.90	101.6	-10.80
Cable Wt. in Water	23.5	22.5	-4.26	27.8	18.30
MDI	2.3	2.39	3.91	1.41	-38.70
No. Factory Splices	4	4	0	1	-75.00
No. At-Sea Splices	0	0	0	0	0
No. Ship Loadings	2	2	0	2	0

NOTES:

1. The MDI for the copper conductor designs is MDI with a joint. All aluminum conductor cases the MDI is WITH a joint.
2. Differences in TI are not significant, since any TI above 2.0 is considered equally acceptable.



- Higher conductivity of conductor material. Smaller conductor could be used.
- More experience with copper conductor submarine cables. Value of this benefit is unclear, since there is positive commercial experience with aluminum conductor submarine cables.

The penalties associated with copper conductor cable designs as compared to an aluminum conductor cable design include:

- Effective deployment/retrieval strength is much lower than aluminum cable designs due to weight and mechanical stress characteristics.

Copper designs with splice = 36 percent lower MDI.

Copper designs without splice = 10 percent lower MDI than aluminum cable designs WITH a splice.

- Cable weight, as compared to the selected aluminum cable candidates (all 250 MW) = Range from 3 to 18 percent higher for the selected 125 MW copper designs and range from 39 to 45 percent higher for the selected 250 MW copper cable designs.

The copper conductor cable designs that include a splice fail to meet the feasibility criterion requiring a minimum mechanical safety factor of 2.0. Copper cable designs without a splice meet

the feasibility criterion of 2.0, but compare poorly to the MDI of the aluminum cable designs WITH a splice. In terms of total technical selection scores, the best copper cable design (with splices) had a total technical score of 1238, which would rank 38th against the aluminum designs. The copper cables provide no significant capital cost advantage. Further, since the best copper cables are all 125 MW designs, system production costs (for high outage case) would be \$100 million higher than the aluminum 250 MW configuration.

The penalties of using copper conductor cable designs significantly outweigh the benefits. Thus, copper conductor cable designs are not considered as final cable "candidates."

## SECTION 12

TECHNICAL EVALUATION OF ALUMINUM  
CONDUCTOR/COPPER TAIL CABLE SYSTEM DESIGNS

In addition to the 192 aluminum conductor and the 59 copper conductor cable designs, a cable design utilizing a solid paper insulated, aluminum conductor cable with copper conductor tails (in shallow waters) was evaluated. This concept was considered since cable design/cost data and cable engineering experience highlighted that:

- 250 MW cable systems are expected to cost approximately \$100 million less than 125 MW cable systems (for high outage rate case).
- The solid paper insulated, aluminum conductor cable designs were not capable of 250 MW rating due to thermal constraints in the shallow water (water ambient temperature 25 degrees C) environment.
- Solid paper cable is considered easier to handle, install and repair compared to SCOF cable.

To provide consideration of a 250 MW solid paper insulated cable system, a 300 kV, 1,400 sq mm aluminum conductor design with copper conductor tails in shallow water was evaluated. Table 18 shows the assumed conditions, expected conductor temperatures and calculated technical scoring.

TABLE 18

BOTTOM CONDITIONS, CONDUCTOR TEMPERATURE AND  
TECHNICAL SCORING FOR  
ALUMINUM CABLE WITH COPPER TAILS

CABLE:

250 MW, solid paper insulated, 300 kV, 1,400 sq mm Aluminum  
conductor; copper conductor tails for shallow waters.

ASSUMED LOAD CYCLING:

400 MW for 8 hours, 500 MW for 16 hours.

TEMPERATURE RESULTS:

BOTTOM CONDITION	CONDUCTOR MATERIAL	CONDUCTOR TEMPERATURE (degrees C)	THERMAL INDEX
-----	-----	-----	-----
BOTTOM			
( 3 degrees C)	Aluminum	46.9	1.07
INTERMEDIATE			
(14 degrees C)	Aluminum	47.3	1.08
SHALLOW			
(25 degrees C)	Copper	42.2	1.44
SHALLOW			
(25 degrees C)	Aluminum	54.9	NG

TECHNICAL SELECTION CRITERIA SCORES:

ITEM	SCORE	WEIGHT FACTOR	WEIGHTED SCORE
-----	-----	-----	-----
MDI	97	5.2	504
TI	7	2.7	19
REPAIR	100	3.4	340
CABLES	75	1.9	143
MANUFACTURE	80	1.4	112
EIO	100	1.0	100
EIT	100	1.1	110
INSTALL	15	3.4	51
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TOTAL SCORE			1379

Utilizing the defined cable selection criteria, the design's total technical score was 1379, thereby ranking it 28th against the other 100 percent aluminum (no tails) cable designs. The major cause of the low technical score is Thermal Index (TI). In intermediate and bottom waters the conductor temperature is approximately 47 degrees C and results in  $TI = 8$ . This compares to  $TI = 100$  for the top, technically ranked SCOF cable designs. There is no cost advantage of using the aluminum/copper tail cable as compared to the higher technically ranked 250 MW SCOF 100 percent aluminum designs. Thus, with no significant technical or cost advantages, the aluminum cable/copper tail cable design concept evaluation was truncated.

## SECTION 13

### FINAL CABLE SELECTION

Based on evaluations of the standard electric design stress, aluminum conductor "candidates" and the alternative electric stress and conductor material designs, it has been determined that an aluminum conductor, standard electric stress cable design best meets all of the cable subsystem feasibility criteria. As such, the selected cable design would be a good candidate for an eventual commercial system. The results of subsequent laboratory and at-sea testing will determine how well the selected design will perform with regard to each of the feasibility criteria.

The final cable design selected for the laboratory and at-sea testing is PCC Case 116. This is a SCOF 25 mm duct cable, 1,600 sq mm aluminum conductor rated at 300 kV, 250 MW, that allows a three-cable configuration.

Based on the broad range of cable design options represented as "candidates," the cable subsystem feasibility criteria do not appear to have been overly restrictive with regard to their effect on cable design selection. The top ranked cable designs and the final cable selection identified using the selection methodology are in agreement with cable designs selected qualitatively by various cable design experts. Thus, the final cable design selection has been made with a high level of confidence.



SECTION 14

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